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PHYSICS FORUM

What's Ahead in Physics*

Karl T. Compton
Massachusetts Institute of Technology, Cambridge, Massachusetts

THE only logical way to predict what is ahead for physics is with reference to past accomplishments and present trends. Experience of the last fifty years shows (1) that some of the great accomplishments of physics are the logical outgrowth of well-planned programs of research and development, while some others are unexpected achievements based on accidental discovery or brilliant imaginative insight. In either case, however, sustained effort on an adequate scale is the prerequisite to achievement; (2) that in the last fifty years physics has exerted a more powerful beneficial influence on the intellectual, economic and social life of the world than has been exerted in a comparable time by any other agency in history. Its influence has far exceeded that of wars, political alignments or social theories.

This is a striking statement which, if true, discloses an equally striking absurdity, for the public is continually excited about this or that issue of politics, tariffs, codes or international relationships which are of far less human import than the past and future accomplishments in that body of science whose American representatives are meeting here today, practically unknown and unnoticed.

To justify my statement regarding the importance of physics, let me call attention first to the fact that the scope of its interests is nothing less than the understanding and use of all the materials and forces of nature. Its main subdivisions, such as heat, light and optics, sound, electricity and magnetism, properties of materials, forces and energy illustrate its scope. Whatever we understand about these subjects and whatever uses are made of such agencies as heat, light, electricity or materials fall within the field of physics and are the contributions of physicists to human welfare.

Not all who are physicists call themselves by that name and therein lies one reason why the average citizen has little comprehension of what physics really is and probably thinks of it only as something vaguely unpleasant. There has been a very interesting historic trend in physics by which great branches of its specialized interests have been appropriated by special groups of physicists who call themselves engineers, just as soon as a systematic method of applying physical principles to advantageous ends has been developed in a specialized field. Thus we have civil engineers, mechanical engineers, automotive engineers, electrical engineers, aeronautical engineers, refrigeration and air-conditioning engineers, mining and metallurgical engineers, motion picture engineers, radio engineers, illumination engineers, communication engineers, chemical engineers, and many others, whose operations are wholly or largely concerned with applying principles of physics to practical ends. Some of these fields, like civil engineering, are very old and based on long recognized physical laws of optics, hydraulics, gravity and strength of materials. Others, like radio engineering, are based upon discoveries made in physical research laboratories within our lifetime. Some of them, like chemical and metallurgical engineering, involve also important applications of chemical science, but of this it may be said on the one hand that the boundary line between chemistry and physics is becoming less and less distinct and on the other that even the chemical engineer has been defined as a "mechanical engineer who knows some chemistry."

In addition to these physicists who are now grouped in special fields as engineers, we have

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astronomers, meteorologists, optometrists and similar groups who deal with physical phenomena, instruments and theories in their special fields of interest.

The basis, therefore, of my statement regarding the intellectual, economic and social influence of physics is placed upon the contributions to knowledge, to industry and to the art of living, which have come from all of these groups which form together the family tree of physics.

Having said this much about the past achievements of physics, what can be said about the present trends? Most significant is the fact that new discoveries and applications are now being made more rapidly than ever before. For example, the modern types of communication, air transport, illumination and electric power have all been developed within the memory of men now living and some of these, like radio, sound and color motion pictures and air transportation, are very young indeed. It would be most illogical to suppose that we have suddenly reached the end of such developments and I think that we can reasonably expect a comparable and perhaps even greater rate of increase in knowledge and practical use of physical materials and forces in the near future.

While I am on this point, let me say a few words regarding a somewhat prevalent fear of physics which has been spread abroad by alarmists and others whose insight is deficient or whose prejudices are excessive. I refer to fear of physical science because the machine, which is one of its products, has taken the place of hand labor and therefore, so it is alleged, has created unemployment. I will not take the trouble to quote census and other figures which indicate that the net result has been in the other direction; namely, that of creating employment. These figures were presented at a joint symposium of the American Institute of Physics and the N. Y. Electrical Society here in New York in February of 1934. What I would like to stress, however, is a point which is generally overlooked; whereas the machine is a product of the older principles of physics, principally of mechanics, the overwhelming majority of present-day activity in physics and its engineering offspring is in lines which will result in entirely new creations, such as new products, new activities and new interests. Air transportation, the automobile, the motion picture and the radio are recent examples on a large scale, and there are multitudes of examples on a small or embryonic scale, such as safety devices, health aids, new household comforts and the like. The social planner and the labor sympathizer can further his particular interest very effectively by supporting efforts to stimulate the effectiveness of modern science in these new creative fields.

Among the practical applications of physics which have been given particular attention in this symposium are included glass, metals, oil, vibrations, building construction and materials, communications, air transport, electric power, illumination, optics and medicine. It is obviously impossible for me to try to suggest what may be ahead in these and similar directions. I might, however, discuss this topic in three large categories. First, those fields of physical application which are themselves built upon recent scientific discoveries; second, those industries which are based more upon ancient art which has been developed largely by practical experience as distinguished from scientific research and discovery; third, those activities which have developed largely on the basis of other sciences such as chemistry and biology. Let me discuss them in this order.

In the first category are included such things as communications, air transportation, motion pictures with sound and color accompaniments, illumination and electric power. Since all of these have been built upon relatively recent scientific discoveries and have been brought to their present stage through intensive research and engineering development, the directors and owners of enterprises in these fields need no convincing that research pays. Their industries have been created by research and their organizations will become obsolete through competition the moment their research activities cease. Self-interest alone insures the continuation of research in these fields and this research will, of necessity, include work in those engineering fields which have been born of physics and also in the aspects of physics which have not yet been formulated into engineering arts, since it is in these latter directions that the newest and

most far-reaching discoveries will come. In other words, engineering is a developed art of the application of existing scientific knowledge, and new knowledge on which to base new art remains continually a field of scientific research whether it be in physics or chemistry and irrespective of whether those engaged in it call themselves engineers, physicists, inventors or by any other designation.

In the second category fall such activities as construction of buildings, highways and dams; production of metals, alloys, glass and textile material; and use of natural resources such as power from coal, oil, water and wind. In all of these fields there is an art which has been handed down from antiquity and which has been more or less improved by invention and discovery of new materials and methods. In these fields there is some tendency for conflict or misunderstanding between the so-called practical artisan on the one hand and the research scientist on the other. The practical man has a great force of tradition behind him and there is a great public inertia against change. In many of these fields the research scientist, for one reason or another, has not been outstandingly successful in improving either products or methods. Yet the trend toward science is unmistakable and is being rapidly augmented. In some cases it is being forced by competition and in others stimulated by example. Few informed technologists would dispute this statement that an application of the methods and knowledge of modern science to these industries, on a proportionate scale comparable to their application to the industries in the first category mentioned above, would yield enormous benefits to the industries and to the public at large. The great problem has been to find some way to put science effectively to work on an adequate scale in these industries.

In some of these industries, earnings have been so exclusively taken out as profits and so little has been put back into the business for development and research that plants and methods have become obsolete and the economic strength has been so depleted that it is difficult to secure the financial support which would be necessary to inaugurate a really effective and promising research program. For some of the units in these industries, the time may have already passed when they can be saved and they will continue to grow more obsolete and eventually be supplanted by more progressive units who have found through scientific research a better product or a more efficient method of manufacture. One thing is certain: the longer an effective scientific approach is delayed, the more serious will be the situation. I might mention specific examples of industries and of units within the industries to illustrate these statements, but this I think is unnecessary.

In an effort to overcome such difficulties in the industries of this category, two movements deserve mention: first are the efforts by the industrial associations to cooperate as a group in establishing scientific studies and research activities for their joint benefit. Second are the efforts by governments to assist these industries to establish research programs, notably in Great Britain, the USSR and in Germany before the war. In this country there has been notable assistance to industry through the Patent Office, the National Bureau of Standards and tariff protection but there has been a most regrettable and short-sighted lack of balance in the policy of government expenditures for the general stimulation of industry. Irrespective of our judgment regarding the justification for large government expenditures to stimulate industry, I think that there would be agreement on the following principle by practically all scientists, engineers and progressive industrialists: "In national, just as in industrial, expenditures, some substantial portion should be devoted to the attempt to improve the products, processes and methods of the future. Huge expenditures for construction and production only, with no provision for research and development aimed at better construction and new production in the future, are woefully short-sighted. Public policy and future industrial welfare require foundations for the future as well as production of the present."

Whatever may be the agency, whether government or industrial association or individual unit in the industry or competitive individual units, it is certain that scientific research to a substantial amount in the fields of physics will be called upon in the building, textile, railroad and other great industries of this class. Obstacles

exist in the lack of vision of some directors on the one hand, and on the other hand the blind faith of those who may expect science to work miracles over night and react against it if this does not occur. Another obstacle is the relative dearth of physicists who have the real interest, training and originality to tackle effectively some of the problems in these more traditional fields where the scientific trail has scarcely been broken. Nevertheless these and similar obstacles will certainly be overcome because we live in an age of scientific progress in which no institution can long be reactionary and survive.

In the third category lie the chemical industries and medicine which have not been founded upon physics but to which physics is contributing an ever-increasing assistance through tools, methods and interpretative concepts. It is primarily to the physicist that the chemist owes his exact knowledge of atomic weights, isotopes, atomic structures and energies, the nature of chemical forces and the atomic arrangements in solids, liquids and gases. It is not possible nowadays to define the boundary between physics and chemistry since physicists, by training, are working on chemical problems and *vice versa.* This rapprochement between chemists and physicists is one of the principal reasons for the extraordinarily rapid advance in both sciences since the beginning of this century.

The significance of physics in medicine may be illustrated by a homely typical example from the life of a doctor. When someone is ill, the doctor is called by telephone, visits his patient by automobile, measures his temperature with a thermometer, his pulse with a watch, examines his heart and lungs with a stethoscope and his throat with a light reflector. Every one of these operations uses a tool and technique supplied by the physicist.

While physics cannot of course claim credit for a major portion of her sister sciences—chemistry, biology or medicine—she can point with justifiable pride to her increasing importance in these sciences. Let me mention briefly only two examples in the field of medicine.

The x-ray has been marvelously developed for diagnostic examination and for therapeutic treatment of certain glandular disorders and growths, notably cancer. Its most recent developments, primarily for investigations of atomic nuclear structure, have had as a by-product exciting new suggestions for medical application. X-rays at a million volts or more have several advantages for treatment of deep-seated cancer. Neutrons produced in nuclear transformations have been shown to possess different effects from ordinary rays from x-ray tubes or radium, and the nature of this difference suggests considerable advantages for their use in therapeutic treatment. Artificially prepared radioactive substances, such as radioactive sodium, offer most interesting possibilities for radium treatments without dangerous after-effects and also open the way to a great variety of new physiological experiments on such things as the rates of blood circulation, digestive processes, tissue building and disintegration, or functioning of various bodily organs.

The second example has to do with physical therapy in general. Many germ and growth diseases can be cured or controlled through the application of some destructive agency to which the germs or diseased growths are more susceptible than a healthy tissue. Such treatments may be said to take advantage of a differential threshold of endurance between the healthy body on the one hand and the material which it is desired to destroy on the other. Undoubtedly only a beginning has been made in developing methods and agents for physical therapy based upon this principle. The treatment of cancer by radium and x-rays, and perhaps soon by neutrons, is based on the fact that the cancerous tissue may be killed by these agents a little more easily than the surrounding healthy tissue.

One of the newest forms of physical therapy which operates on this differential threshold principle is based upon resistance to temperature. There is some temperature characteristic of any living organism above which it cannot live. It has recently been found that this temperature is lower for the organisms that produce distemper in dogs than it is for the dogs themselves. Consequently dogs may be cured of distemper by producing in them an artificial fever which raises the temperature above the threshold limit for the diseased organisms while still safely below the threshold limit for the dog. In a similar manner, syphilis may be cured in mon-

keys, although in man the two threshold temperatures are so close together that it is extremely risky to attempt a cure by this method. Very recently, however, an improved technique has been developed which offers great promise for many applications and which consists of raising bodily temperature locally by means of electromagnetically produced high frequency electric currents within the body in the region to be treated while the temperature of the body as a whole is kept within the safe limit by special cooling.

In the face of these discoveries of neutron and localized heat therapy and a great many similar applications of physics to medicine, which are only a few years or only a few months old, it does not take any great gift of prophecy to justify a belief that physics is going to make great new contributions to human welfare through its applications in medicine in the near future.

In conclusion I would summarize my belief in the future of physics by the following analogy. During the past third of a century, the discoveries of the electron, the x-ray and radioactivity have together brought about the greatest advances which have ever been made in fundamental knowledge of the physical world and in practical applications of this knowledge of human welfare. These developments will undoubtedly continue. It may very well be that the new fields of knowledge disclosed through exploration of the atomic nucleus may bring about a new set of developments of corresponding importance before this century comes to a close. It is primarily in the groups represented by the five member societies of the American Institute of Physics that those things which are next in physics, some of which we can anticipate and some of which are certainly quite unknown to us, will come to pass.

BRIEF NOTICES OF NEW BOOKS

Ein neues elektrisches sprechgerat zur nachbildung der menschlichen vokale. KARL WILLY WAGNER. Pp. 44, Figs. 44, $19\frac{1}{2}\times 27$ cm. Verlag der Akademie der Wissenschaften, Berlin, 1936. Price RM 3.

Essential Principles of Organic Chemistry. CHARLES S. GIBSON, professor of chemistry, University of London at Guy's Hospital Medical School. Pp. 348+viii, $14\frac{1}{2}\times 22$ cm. University Press, Cambridge and Macmillan Company, New York, 1936. Price $5.00.

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Properties of Matter. F. C. CHAMPION AND N. DAVY. Pp. 296+xiv, 15×22 cm. Prentice-Hall, Inc., New York, 1937. Price $4.50.

Report of the Committee on the Measurement of Geologic Time. ALFRED C. LANE, chairman. Pp. 87, 21×27 cm. Mimeographed. National Research Council, Division of Geology and Geography, Washington, D. C., 1936.

Statistical Mechanics. The Theory of the Properties of Matter in Equilibrium. R. H. FOWLER, fellow of Trinity College and Plummer professor of mathematical physics, University of Cambridge. Second edition, revised and enlarged. Pp. 864, Figs. 101, 19×27 cm. University Press, Cambridge and Macmillan Company, New York, 1936. Price $14.00.

Textbook on Spherical Astronomy. W. M. SMART, John Couch Adams astronomer in Cambridge University and University lecturer in mathematics. Second edition. Pp. 430+xii, Figs. 149, 14×22 cm. University Press, Cambridge and Macmillan Company, New York, 1936. Price $5.50.